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CONF-840842--4

TITLE: DYNAMICAL SCALING IN ^{3}He-^{4}He LIQUID MIXTURES

LA-UR--84-905

DE84 010072

AUTHOR(S): James K. Hoffer and Dipen N. Sinha

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DYNAMICAL SCALING IN ^{3}He-^{4}He LIQUID MIXTURES*

James K. HOFFER and Dipen N. SINHA[+]

Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.A.

Light scattering data in decomposing ^{3}He-^{4}He mixtures yield the normalized dynamic structure factor $\bar{S}(k,t)$ and verify the dynamic scaling hypothesis $\bar{S}(k,t) = k_1^{-3} F(k/k_1)$, where k_1 is the first moment of the (unnormalized) structure factor $S(k,t)$, and $F(x)$ is a time independent "shape" factor. Assuming that scaling is also valid for $S(k,t)$, we trace the path of the quench in the temperature-composition plane.

1. INTRODUCTION

We have previously presented (1) light-scattering intensity data for decomposing ^{3}He-^{4}He liquid mixtures that suggested the validity of the dynamical scaling hypothesis (2):

$$\bar{S}(k,t) = [K(t)]^{-3} F[k/K(t)] , \qquad (1)$$

where $\bar{S}(k,t)$ is the normalized dynamic structure factor, $F(k/K)$ is a time-independent shape function, and K^{-1} is a measure of the time dependent domain size with

$$[K(t)]^{-1} \propto t^\phi . \qquad (2)$$

Here, we present new data having much higher precision. Following Craievich and Sanchez (3), we evaluate our data by first calculating the unnormalized n-th moments of the structure function $S_n(t) = \int k^n S(k,t) dk$. A consequence of the scaling hypothesis is that $S_n(t) \propto [K(t)]^{n-2}$ and therefore S_0/S_1^2 should be a time-independent constant. Likewise, for the normalized moments $k_n(t) = S_n(t)/S_0(t) \propto [K(t)]^n$, we expect that the ratio k_2/k_1^2 should be constant. These two ratios are related by the total integrated scattering intensity S_2: $S_0/S_1^2 = (1/S_2) k_2/k_1^2$, and therefore S_2 is itself expected to be constant. S_2 is also the proper function for normalizing the raw intensity $S(k,t)$ to the dimensionless function $\bar{S}(k,t) = S(k,t)/S_2$ appearing in Eq.1.

2. EXPERIMENTAL

We continue to use the pressure-jump technique to initiate a deep quench into the miscibility gap (see Fig. 1); but the sample cell has been redesigned with two opposed bullows to permit a more isotropic decompression of the mixtures without introducing any noticeable convection which might influence the decomposition processes. We use a linear photo-diode array (5) with smaller active elements and wider inter-element spacing compared to the previous array. Our angular resolution is thus improved and we no longer need to mask the array to preserve the resolution at low angles. The angular intensities $I(k,t)$ are electronically divided by the separately measured intensity of the unscattered laser beam $I(0,t)$ to yield $I'(k,t) = I(k,t)/I(0,t)$, thus correcting the data for effects of multiple scattering. After correcting for the background intensity $I'(k,0)$, we equate $I'(k,t)$ with $S(k,t)$. We also identify the origin of time t in the decomposition process by the kink in $I(0,t)$ observed when scattering first occurs.
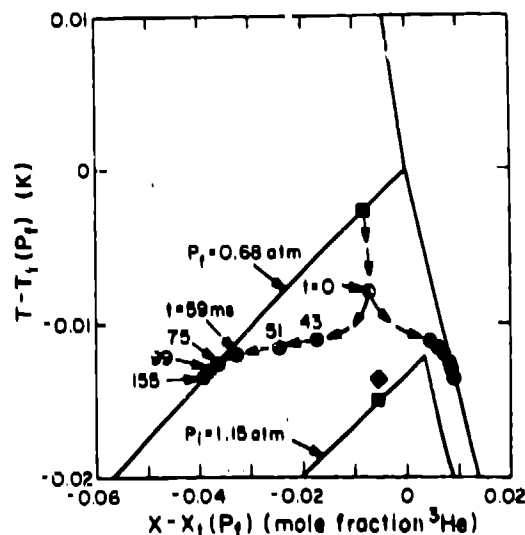

FIGURE 1. Location of initial, final and intermediate states during a pressure-induced quench.

3. RESULTS AND DISCUSSION

We present the results of a typical quench into the miscibility gap for which the initial pressure P_i is 1.15 atm. The total composition is close to the tricritical value for the final pressure P_f = 0.68 atm. At the initial temperature, the mixture is already phase separated. The laser beam is positioned in the lower, superfluid phase and we ignore the simultaneous decomposition which occurs in the upper, normal phase. The initial state is shown as the lower solid square in Fig.1. If the decompression were instantaneous, the resulting state would be as indicated by the solid diamond in Fig. 1, (the slight temperature rise being due to the adiabatic heat of expansion) and this state would subsequently decompose because it lies deep within the miscibility gap. Equivalently, we may consider the quench entirely with respect to P_f, where the initial state is represented by the upper solid square. Because the decompression (or equivalent lowering of temperature) proceeds with finite rate, the system first begins to decompose after crossing the cloud point, labeled t=0 in Fig. 1. The degree of anomalous supercooling is quite obvious here(6). The photodiode array was started 35 ms later, and we recorded 16 scans at 8 ms intervals. The first scan showed no detectable scattering and was used to correct for the background. Each scan of intensity was fit to a Lorentzian function only for the purpose of extrapolating the data to higher wave numbers, when necessary, thereby allowing a consistent evaluation of S_n by summing k_n $S(k,t)$ from k = 0 to k = 3 k_1 for n values of 0, 1, and 2. The resulting moments and scaling ratios are listed in Table 1.

TABLE 1. Time evolution of the moments of the dynamic structure function in a 3He-4He mixture.

Scan	t (ms)	S_2 (10^{13})	S_0/S_1^2 (10^{-14})	k_1 (cm^{-1})	k_2/k_1^2
2	43.	1.217	9.696	10616.	1.180
3	51.	2.434	4.846	9352.	1.179
4	59.	4.076	2.928	8053.	1.193
6	75.	5.292	2.273	6050.	1.203
8	91.	5.303	2.276	4556.	1.207
10	107.	5.501	2.174	3685.	1.196
12	123.	5.881	2.050	3085.	1.206
14	139.	5.902	2.070	2654.	1.222
16	155.	6.018	2.050	2493.	1.234

It is seen that the ratio of normalized moments k_2/k_1^2 is nearly constant, with only a very slight dependence on time. If we identify k_1 with $K(t)$, the data verify Eq. 2, with ϕ = 1.22 ± 0.10. In Fig. 2, we test Eq. 1 by plotting $F(k/k_1)$ = k_1^3 $S(k,t)$ for scans 2 through 10. Scans 11 through 16 fit the scaling function equally well, but are not shown here.
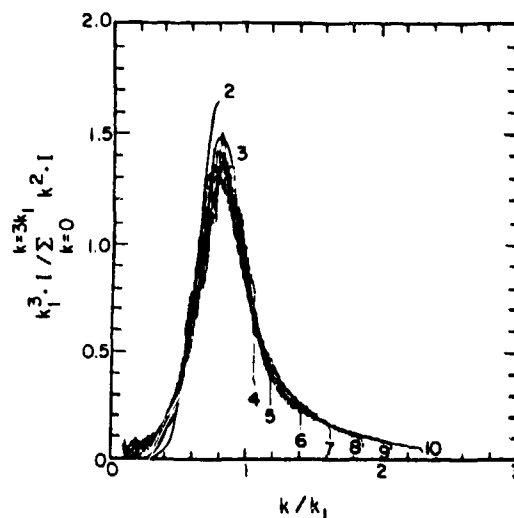

FIGURE 2. Scaling of the normalized structure function in a decomposing mixture of ^{3}He-^{4}He.

The ratio S_0/S_1^2 in not constant, due largely to the time dependence of S_2. However, the true total integrated intensity contains a factor proportional to ΔX^2 (7), where ΔX is the time-dependent difference between the instantaneous concentrations of the two evolving species. If we assume S_2 is constant, we can calculate ΔX at the time of each scan, normalized to the value given by the phase separation lines at t= ∞. The resulting values of ΔX have been plotted as pairs of solid circles in Fig. 1. Note that we have calculated ΔX, not the individual concentrations of the two evolving states, so that the placement of the circles in Fig. 1 is somewhat arbitrary. Nonetheless, the data seem quite reasonable, showing that for scans 6 through 16, the values of ΔX are just what one expects if the evolving species are at their equilibrium values. For the earlier scans, the evolution of ΔX proceed smoothly from ΔX = 0 at t = 0, at a speed consistent with the tricritical slowing-down expected for dynamic processes within about 10 mK of the tricritical temperature (4).

REFERENCES
(1) D. N. Sinha and J. K. Hoffer, Physica (Utrecht) 107B (1981) 155. (LT-16)
(2) J. Marro, J. L. Lebowitz, and M. H. Kalos, Phys. Rev. Lett. 43 (1979) 282.
(3) A. Craievich and J. M. Sanchez, Phys. Rev. Lett. 47 (1981) 1308.
(4) D. N. Sinha and J. K. Hoffer, Phys. Rev. Lett. 50 (1983) 515.
(5) D. N. Sinha and J. K. Hoffer, in print.
(6) D. N. Sinha and J. K. Hoffer, this volume.
(7) Y. C. Chou and Walter I. Goldburg, Phys. Rev. 23A (1981) 858.